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FOREWORD

The preparation of these guides has been a joint undertaking of research and national forest administration. Reviews and suggestions of other members of the Station who are active in northern hardwood research were helpful, especially those from men working at the Upper Peninsula Research Center in Marquette, Mich., and the Northern Lakes Research Center in Wausau, Wis. Numerous field conferences helped to integrate research results and thinking with the experience of national forest managers. The advice and suggestions of industrial foresters and timberland owners provided additional ideas.

Cover picture: A stand of old-growth northern hardwood shortly after the initial selection cut.

MARKING GUIDES FOR NORTHERN HARDWOODS UNDER THE SELECTION SYSTEM

by

Carl Arbogast, Jr.

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Lake States Forest Experiment Station St. Paul 1, Minn.
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MARKING GUIDES FOR NORTHERN HARDWOODS UNDER THE SELECTION SYSTEM

by

Carl Arbogast, Jr.[1/]

PURPOSE OF REPORT

The purpose of this report is to provide a working tool for marking timber stands under the selection system of management in the all-aged northern hardwood forest of the Lake States. Stand conditions are described, and marking guides are given not only for properly regulated stands but also for irregular or unmanaged stands whose owner wishes to develop the conditions recommended for a productive forest.

Since the objective of the report is to present the material in a form that will be most useful to practicing foresters, explanations of the basis for recommended treatments have been reduced to a minimum, and publication credits have been omitted. A bibliography, however, has been included in the appendix for those who wish to review the material on which the report is based.

No attempt has been made to discuss the formulation of cutting policy on the part of landowners, nor has any discussion of the advantages and disadvantages of the recommended system been included in the report, as this is outside its scope.

The term "Guide" was used in the title after careful consideration of such terms as "Rules" or "Instructions", because it implies more flexibility in application. The present status of knowledge of management practice in northern hardwoods does not permit the statement of rigid rules.

One point concerning the stocking levels mentioned throughout the report should be kept in mind: The figures used, in terms of square feet of basal area per acre, are the midpoints of a range, and a tolerance of plus or minus 10 square feet per acre is permissible.

1/ Research forester at the Upper Peninsula Research Center, a field branch of the Lake States Forest Experiment Station. The Station's headquarters are maintained at St. Paul 1, Minn., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Minnesota.

Finally, the author would like to emphasize that this report has been prepared to assist trained professional foresters in marking northern hardwoods in the Lake States for the landowner whose policy is the maximum production of high-quality hardwood timber. Where this type of production is not the intent of the landowner, these marking guides may not apply.

THE NORTHERN HARDWOOD FOREST

The Society of American Foresters lists the following group of types in the Lake States as making up the northern hardwoods:

Sugar maple-beech-yellow birch
Sugar maple-basswood
Sugar maple
Hemlock-yellow birch

Despite the fact that a number of separate types can be identified, the transition between them is often indefinite and their reaction to treatment is so similar that they can be grouped together for discussion of major management recommendations.

Considering the northern hardwood forest as one broad cover type and including with it the hemlock type and its variants, the principal species are sugar maple, eastern hemlock, yellow birch, basswood, and American elm. Frequently associated with the above are balsam fir, white pine, white spruce, red maple, and ironwood (eastern hophornbeam). Northern red oak and rock elm are important associates in some localities. Beech is widespread in the eastern part of the Lake States area, but nonexistent or of very minor importance in the western part.

In addition to the several different cover types which, when grouped together, are called the northern hardwood forest, there are any number of stand condition classes within each type. These differences are caused by past methods of stand treatment, fire, wildlife, and the influence of soil and site.

RECOMMENDED SILVICULTURAL SYSTEM

The selection method of cutting with certain modifications is recommended for the management of northern hardwoods. Under this all-aged system of sustained yield forest management, a stand of high-quality trees is developed and maintained by removing the poor trees over the entire range of size classes, and the mature and overmature trees through a continuing series of partial cuts made at relatively short

intervals (8 to 15 years). The concensus of both research and management people in the Lake States is that this system is well suited to produce good yields of high-quality timber.

The selection method has been studied in the Lake States over a long enough period and trials have been extensive enough so that definite recommendations can be made for its application. The potentialities of even-aged silviculture are essentially unknown as yet.

The application of selection silviculture usually requires that the character of the existing forest be changed to provide for continuous growth and desirable reproduction. These changes mostly concern stand structure, but species composition and quality are also involved.

Stand Structure

Based on interpretation of experimental results, a model of stand structure and stocking has been developed that, if attained in practice, will yield good growth, continuous ingrowth, and seedling reproduction rather than sprouts (table 1).

Table 1.--Desirable stocking per acre for good continuous growth

Diameter at breast height (Inches)	Desirable stand after cutting		Diameter at breast height (Inches)	Desirable stand after cutting	
	Trees	Basal area		Trees	Basal area
	Number	Square feet		Number	Square feet
2	118)	2.6)	15	4)	4.9)
3	53)202	2.6) 8	16	4)	5.6)
4	31)	2.7)	17	3)17	4.7)26
5	21)	2.9)	18	3)	5.3)
6	15)	2.9)	19	3)	5.9)
7	12) 65	3.2)16	20	2)	4.4)
8	9)	3.1)	21	2)	4.8)
9	8)	3.5)	22	2) 8	5.3)20
10	7)	3.8)	23	1)	2.9)
11	6)	4.0)	24	1)	3.1)
12	5) 28	3.9)22			
13	5)	4.6)	Total	320	92
14	5)	5.3)			

This table presents the desirable structure of the residual stand immediately after cutting. When such a stand has been developed, it should remain thrifty and, if cut at fairly short intervals (8 to 15 years), should maintain good periodic growth continuously. For the purpose of discussion and application, the figures in this table have been summarized and presented in a different form in table 2.

Table 2.--Summary of desirable stocking recommendations

Crown class	Tree size	Normal d.b.h. range	Recommended stocking
		Inches	Square feet
Dominant	Sawtimber	10+	65-75
Intermediate	Poles	5-9	10-20
Suppressed	Saplings	2-4	5-10

Stocking is expressed in terms of basal area rather than as number of trees, board-feet, or cords because basal area is a more useful expression of total growing stock when broad diameter groups are considered.

This guide (table 2) can be used for marking northern hardwood forests under an uneven-aged form of management anywhere in the Lake States. The user should remember that it is an interim guide developed in one locality and based on only 20 years' observation of stand behavior. It is believed to be reliable and conservative, but it is being checked constantly and will be refined as more data become available.

The implications of the guide or model may be more easily recognized when the reasons for the prescribed stocking in the various levels are understood. In the sawtimber portion of the stand the guide recommends leaving 65 to 75 square feet of basal area per acre in trees 10 inches to 24 inches d.b.h. This stocking provides for good growth and maintenance of quality within the sawtimber level and also allows sufficient light through the dominant canopy to permit growth and development of the understory.

The 10 to 20 square feet of basal area to be left in pole-sized trees is sufficient to insure a nucleus for continuous movement of trees into the sawtimber sizes. At the same time it will permit light to reach and encourage development of the saplings underneath. Where light is adequate, the saplings will develop rapidly and replace the poles that

have grown into sawlog sizes or have been harvested. In other words, there will be sufficient light under a stand of 85 square feet of basal area per acre to permit established seedling reproduction and saplings to develop at a satisfactory rate.

Finally, if the entire stand of saplings, poles, and sawtimber contains 95 square feet of basal area, seedling reproduction will establish itself and sprout reproduction will be inhibited.

When the stand structure shown in tables 1 and 2 is attained, the forest will produce continuously, perpetuate itself, and produce a good quality and quantity of growth.

Kind and Size of Trees

A stand of timber is only as good as the trees in it. The structure guide indicates the distribution and stocking of tree sizes desirable for all-aged management. Ideally, all of these trees should be thrifty and vigorous, and those permitted to remain in the stand until maturity should be of high quality.

Most hardwood stands contain large numbers of highly defective and poorly formed trees in addition to those of unwanted species. Though very few perfect trees are found in unmanaged stands there usually is a recognizable range from good to poor. The timber marker, therefore, should remove the trees with the poorest silvicultural and economic characteristics and leave the best ones. Because of the large number of poor trees and because it usually is easier to select trees to cut than to leave, markers inexperienced in hardwood management tend to cut too heavily.

Good growing stock, by definition, possesses a capacity for development into valuable timber in the future. Trees that are left should be vigorous enough to grow rapidly, have a form suitable for the production of high quality wood, and be free of major defects. Ideally, a residual tree should be sound, single stemmed, fine limbed, full crowned, and free from crook or lean, and should have a bole clear of limbs up to one-third to one-half of its total height. A guide which divides trees into four classes based on relative quality is given in the appendix.

When deciding which trees to cut and which to leave in reducing the stocking to the desired level, the marker must take the following items into consideration in the order in which they are given:

1. Risk: Any tree should be removed that, in the judgment of the marker, will not live and grow until the next cut.

2. Cull: Cull and highly defective trees that will not increase in value during the cutting cycle should be removed.

3. Form, crown, and branching habits: Crooked or leaning trees, those with an acute angle between limbs and bole, and those with short clear length or large limb diameter should next be considered for removal.

4. Species: Low-quality timber has about the same value regardless of species, but large differences in value between species exist when physical quality is high. Therefore, after the low-quality trees described in items 1 to 3 have been removed from the stand, difference between tree species should be the next consideration. Yellow birch, basswood, and sugar maple should be favored, while red maple and beech should be discriminated against in most cases. However, relative species values vary greatly according to local market conditions. It is therefore not possible to make a ranking of species by value that will apply rigidly to an area as large as the Lake States. Species value should be determined locally.

5. Crown position: In addition to the above items the position of a tree in relation to the other trees to be left in a stand should be considered. The marker should mark for removal trees interfering with the full development of other trees of higher potential quality, thus providing the better trees freedom for crown development in all directions.

6. Size: Finally, tree diameter should be considered. Generally speaking, most tree species within the northern hardwood type become economically mature when they reach 20 to 24 inches d.b.h. Trees that have reached, or grown beyond, economic maturity do not pay their way in comparison to smaller trees.

Summary

1. All-aged management is recommended.

2. Marking of each individual tree is based on: risk, cull, quality, vigor, species, crown position, and size. These are in general order of importance. It is essential that the marker weigh all the characteristics of each tree.

3. Marking should aim at developing and maintaining the stand structure given in tables 1 and 2.

4. The entire discussion in this section can be reduced to two general rules for all-aged management of the northern hardwood cover type:

   a. Leave enough trees in each segment of the stand structure to provide adequate stocking and size class distribution for optimum stand development and growth, using table 2 as a guide.

   b. Select trees to leave that have the highest potential for maximum quantity and quality growth.

APPLICATION OF THE RECOMMENDED SYSTEM

The rules presented in the previous section are simple, but their application is somewhat more complicated because of the extreme variability of the northern hardwood forest. Unregulated tracts display almost infinite variations in stocking, structure, composition, and quality. However, despite the lack of uniformity over large areas, the unregulated forest consists of small, readily recognized, homogeneous groups of trees about one-half to one acre in size or smaller. Thus, the timber marker must apply a different prescription to each recognizable stand variation to develop the recommended stand structure, composition, and quality needed in a productive forest.

It may take three or four cyclic cuts or more in an unregulated forest before the structure and quality necessary for high level production are developed. After the regulated stand is attained, application of the two rules discussed in the previous section should maintain suitable conditions for optimum growth in volume and quality. Silvical requirements of an especially desirable species such as yellow birch will call for minor modifications.

The major problem in our present stands is how to attain the structure and quality desired in a regulated forest. This will be emphasized later. However, the logical starting point for discussion is the application of the marking guides to stands that have a proper distribution of size classes.

Marking in Fully Regulated Stands

A fully regulated stand is recognized by the presence of good quality trees in all diameter classes (fig. 1 on next page). All elements of stand structure before cutting will be stocked at or in excess of the

Figure 1.--Northern hardwood stand before third cyclic cut; desirable structure has developed.

recommended stocking shown in table 1, and trees larger than the maximum size shown in the table will be present. In other words, there will be more than 70 square feet of basal area in trees 10 inches d.b.h. and over, more than 15 square feet of basal area per acre in trees 5 to 9 inches d.b.h. and more than 10 square feet of basal area per acre in trees 2 to 4 inches d.b.h. Consequently there will be more than 95 square feet of basal area per acre in the total stand 2 inches d.b.h. and over.

Silvicultural Objective

The objective of marking in this type of stand is to maintain desirable quality and stand structure at optimum levels of basal area stocking.

Recommended Treatment

1. Harvest the mature timber. Maturity in northern hardwoods is a matter of economics rather than age. While the size of an economically mature tree varies with the markets, species, and tree quality, the better quality trees can generally be considered economically mature when they have attained from 20 to 24 inches in diameter at breast height.

2. Reduce the stand above 10 inches d.b.h. to 70 square feet of basal area per acre by removing the poorest trees but leaving adequate stocking in all diameter classes in the residual stand. This is a combined improvement, thinning, liberation, and salvage cut.

3. Reduce the stocking of poles (5 to 9 inches d.b.h.) to 15 square feet of basal area per acre, again leaving the best trees well distributed among all sizes represented in the residual stand. Desirable species should be favored over the less desirable ones and seedlings over sprouts. This is a combined cleaning, thinning, and improvement cut.

4. Reduce the sapling stand to 10 square feet of basal area per acre of desirable species. It is difficult to identify good growing stock before the trees have reached pole size; therefore, if cutting is considered practicable in the sapling portion of the stand, seedlings should be favored over sprouts and the more desirable species favored over the less desirable ones.

Theoretically, regulated stands should be cut in all levels of stand structure, even at some out-of-pocket expense, in order to prevent future voids in the size-class structure and to be sure that only vigorous high-quality trees grow into sawtimber.

Applying Selection Silviculture to Irregular Stands

The unmanaged or mismanaged northern hardwood forest displays great variation in stand structure, composition, and quality. Some of this variation, especially in composition, is no doubt caused by site quality differences. Most of the differences in structure, however, are related to stand history. Quality differences may be the result of the influence of both site productivity and past treatment. In any case, quality growth should be stimulated, as has been previously discussed--that is, by removing the trees with the poorest silvicultural or economic characteristics, leaving the best trees to grow. The wild or unmanaged stand is generally overstocked in some size classes and deficient in others. The silvicultural objective of marking is to develop the understocked portion of the stand by providing sufficient light to permit individuals in the next lower layer to grow into the deficient layer at a maximum rate consistent with quality. Sufficient stocking must be left in the overstory to inhibit both sucker and sprout reproduction, and epicormic branching on the boles of the residual trees.

Although the objective is the same in all cases, application of the marking guides differs depending on whether or not the overstory or the understory is deficient.

Marking a Stand Overstocked with Sawtimber and Understocked with Saplings and Poles

Overstocking in sawtimber is most common in virgin northern hardwood stands (fig. 2) but also may be found in partially cut stands where the previous cut was too light for the length of the cutting cycle. Second-growth stands generally have small areas in this condition where accessibility, quality, or size originally prevented cutting. These stands are easy to recognize without measurements, as they are parklike in appearance and are free of "underbrush". However, abundant low reproduction may be present.

In this type of stand only the prescribed level of stocking in the sawlog-size classes is considered. The sawtimber portion of the stand should be reduced to 70 square feet of basal area per acre. The existing poles should be carefully scrutinized, and those that will not produce quality timber in the future should be removed regardless of the prescribed stocking levels. No attention need be paid to the saplings or reproduction at this time.

A stocking of 70 square feet of basal area per acre in the overstory will inhibit sprout reproduction but will admit ample light for rapid growth of both the residual sawtimber and the seedling understory. The

Figure 2.--Northern hardwood stand overstocked with sawtimber and understocked with small timber.

Figure 3.--Northern hardwood stand understocked with sawtimber and overstocked with small timber.

removal of all low-quality poles is recommended because these would otherwise be the first to enter the sawtimber size from the understory. Considerable time and money will be wasted if such trees are permitted to grow and benefit from release, and eventually are no more than cull or low-quality trees. Their removal immediately will permit seedlings and saplings to develop more rapidly to take their place. If no market exists for low-grade pole-size trees, cutting, girdling, or poisoning is recommended for improvement of the understory.

Marking a Stand Understocked With Sawtimber But Overstocked With Smaller Timber

Stands understocked with sawtimber but overstocked with smaller trees (fig. 3) are where the merchantable overstory was completely removed during earlier logging. Partially cut stands where diameter-limit designation was used also may have this structure. It may be found too in patches of virgin stands where wind or other catastrophic agent has created openings in the forest.

When a stand is overstocked in poles and deficient in sawtimber, the total stocking of intermediate and larger trees in table 2 is used as a guide. This stock should be reduced to 85 square feet of basal area per acre as recommended for poles and sawtimber. Where the total stocking of poles and sawtimber is less than 85 square feet of basal

area, the marker concerns himself with the entire stand of saplings, poles, and sawtimber.

As the size of the trees considered by the marker decreases, the amount of residual basal area recommended increases. This recommendation results from the sprouting habits of most of the components of northern hardwood stands. The smaller the tree, the more likely it is to develop epicormic sprouts, stump sprouts, and root suckers. The stocking figures in relation to sprouting are based on general observations and should be used as relatively flexible guides. In any case, if the stocking level is reduced by more than about 10 square feet per acre below the recommended level, there is real danger that the poor growing stock removed will be replaced by even poorer trees of sprout origin.

Another consideration is the need for an adequate source of seed of desirable species. Sugar maple and other species of the more desirable hardwoods do not bear viable seed in any amount until they reach ages in excess of 50 years (about 10 inches d.b.h.) On the other hand, less desirable species such as red maple often bear seed at a very early age. Therefore, if all the trees of sawtimber size are culls or otherwise defective and are cut, any reproduction obtained will be either sprouts or of the less desirable species, and openings may become sod bound and therefore nonproductive for an extended period of time. To avoid this, it is desirable to leave some well formed, though defective, trees as a seed source until younger individuals reach seed-bearing age.

As modified by the above discussion, priority of cut in stands understocked with sawtimber should be as follows:

a. Remove cull and defective overstory trees, but do not cut any good growing stock in the overstory.

b. Reduce the stand to the desired stocking by cutting in the pole-sized portion of the stand to favor the better growing stock.

Stands Understocked Throughout the Entire Structure

Understocked stands can be encountered in all types of northern hardwood forests--virgin, partially cut, or second-growth (fig. 4 on next page). No cutting is recommended where this condition is encountered.

Figure 4.--Northern hardwood stand understocked in all elements of stand structure.

MODIFICATION OF RECOMMENDED SYSTEM FOR SPECIAL CONDITIONS

To Perpetuate Yellow Birch

Yellow birch is less tolerant of shade than sugar maple. To insure its continuance in partially cut hardwood forests, three requirements are essential:

1. Make provision for sufficient light by creating small openings (about 1/10 acre) throughout the stand.

2. Assure ample seed supply by leaving seed trees within 300 to 400 feet of openings in dense stands.

3. Expose mineral soil for seedbed by summer or fall logging or by mechanical scarification.

Even though yellow birch is relatively intolerant and requires the above provisions for successful regeneration, it has been demonstrated that the small seedlings, once established, require partial shade for optimum development. Therefore, where clearcut openings are made they

should be kept small, 1/10 to 1/5 acre. Once birch is established, release cuttings may be necessary to make sure it is not crowded out by sugar maple.

It is not the intention here to recommend the group-selection method indiscriminately, but only where suitable conditions prevail. For example, where there are defective maples close to yellow birches that could be left as seed trees, the single-tree selection system could well be modified to create a group opening by removing the maples and leaving the birches.

To Manage Large Areas of Hemlock-Yellow Birch

The hemlock-yellow birch timber type is found on extensive areas in northern Wisconsin and Upper Michigan as well as in small patches in the sugar maple-yellow birch type. Where the type is found on large areas, a major modification of the basic hardwood recommendations is needed.

Attempts to apply selection cuttings to overmature hemlock stands have met with little success. There is much likelihood, however, that seedling reproduction of the more desirable hardwoods will be favored if the old hemlock is removed in a series of selective cuts.

Both yellow birch and hemlock are sensitive to exposure. When the trees are overmature or of low vigor they may become decadent or die after partial cutting. Vigorous trees are less seriously affected, and when injury does occur they are more likely to recover without serious loss of growth or quality.

About 90 percent of the mortality that occurs in hemlock-birch stands takes place within 5 years after the initial cut. It is more severe along road cuts, in large openings, and among trees whose boles are exposed to direct sunlight in the southwest quarter. Little mortality occurs after the second and third partial cuts.

To summarize the reasons for modification of the basic hardwood recommendations in managing the hemlock-birch type:

1. Both hemlock and yellow birch are very sensitive to exposure following cutting.

2. Yellow birch requires different light and seedbed conditions for successful regeneration than do the more tolerant hardwoods.

3. Yellow birch and hemlock trees that are overmature and of low vigor are more likely to die or become decadent after partial cutting than are the thrifty ones.

4. Most of the mortality can be expected during the first 5 years after cutting.

5. Mortality following second and third cuts is generally much less than after the initial cut.

The above characteristics of hemlock and yellow birch lead to the following recommendations for managing this timber type:

1. Make an initial cut leaving 100 to 110 square feet of basal area per acre of sawtimber-sized trees.

2. Make a planned salvage 3 to 5 years after the initial cut removing the usable dead trees and trees obviously dying.

3. At the time of the salvage cut if sufficient sawlog stocking remains, reduce the basal area to between 70 and 80 square feet per acre. If natural mortality has not created enough openings, more can be made at this time. Large-sized birch trees exposed to direct sunlight on the southwest quarter of the bole should be considered for removal at this time.

4. After the salvage cut, the stand should be put on an 8- to 15-year cutting cycle; subsequent marking can follow the general recommendations for northern hardwoods.

When Markets Are Limited

The marking rules as discussed contemplate a market for all products to be removed from the stand. Generally this sort of market exists only rarely. Where the market for some of the products is limited it is up to the landowner to decide whether to incur an expense now to assure greater future production in volume and quality. His problem usually is whether or not to cut or deaden cull trees in the sawtimber and pole sizes.

If cull trees are left in the stand, they must be considered as part of the residual stocking because cull trees often live, grow, and cast shade in the same manner as sound trees for many years. If they are not considered as part of the stocking, stand development will be seriously delayed since portions of the stand can remain overstocked only at the expense of other portions. A still worse solution is to consider cull trees as a portion of the stand stocking and remove better trees to bring the stand to the prescribed levels, whereupon serious deterioration of the stand quality and growth will result. It is strongly recommended that cull trees be removed, regardless of market conditions, where their removal is called for under the marking guides. This need not be an expensive job as the trees do not have to be cut down to eliminate them from the stand. They may be girdled or poisoned either during or after logging.

SUMMARY OF RECOMMENDATIONS

Stand condition	Stand description before cutting	Recommended treatment
1. Fully regulated.	All elements of structure stocked in excess of recommendations.	Harvest mature timber. Reduce stocking of timber (10"+) to 70 square feet of basal area per acre, poles to 15 square feet, and saplings to 10 square feet.
2. Overstocked with sawtimber but understocked with smaller timber	Stand is parklike and free of "underbrush". Abundant small reproduction may be present. Commonly found in virgin stands.	Reduce dominant sawtimber portion of stand to 70 square feet of basal area per acre. Remove poles that will not produce high-quality timber in the future.
3. Understocked with sawtimber but overstocked with smaller timber.	Most commonly found in second-growth stands. Stand has even-aged appearance.	Reduce stand to 85 square feet of basal area in poles and sawtimber together. Remove cull and defective overstory trees. Cut only poor growing stock in overstory. After defective overstory trees have been removed, reduce stand to desired stocking by cutting in pole-sized portion of stand. If no sawtimber is present, reduce poles to 75 to 85 square feet of basal area per acre.
4. Understocked throughout entire structure.	Open, brushy stands. Grass, sod, or raspberries and other brush species predominant in understory.	No cutting recommended.
5. Overstocked with sawtimber; hemlock and/or yellow birch predominate.	Stand structure similar to No. 2 above with either hemlock, yellow birch, or both predominant.	1. Make initial cut leaving 100 to 110 square feet of basal area per acre of sawtimber-sized trees. 2. Make planned salvage 3 to 5 years after initial cut. 3. At time of salvage, reduce sawtimber to 80 square feet per acre. 4. Subsequent cuts similar to those recommended for stand condition No. 2.

APPENDIX

A Tree-Class Guide for Marking Northern Hardwoods

Selection silviculture calls for an appraisal of the relative quality of growing stock. Some trees are to be cut and some left, and the basis for choice is the relative potential of each tree for future development. The information on which the decision is made for the most part is generalized knowledge of how trees have developed in the past under various stand conditions. This has been formalized in the following classification for ready reference:

Tree class one: Good growing stock.--The tree must be straight, dominant or codominant, free from crook or lean, and with less than 10 percent cull. An average of at least 50 percent of the total height of the tree must be in clear length.[3/] In trees 9 inches or less in diameter at breast height, limbs and knots under 1 inch in diameter may be permitted in clear length. The crown should be full and the vigor good.

Tree class two: Satisfactory growing stock.--Trees of intermediate crown class or better are permitted in this class. The trees may have no defect of crook or internal decay involving over 20 percent cull. Trees must not have acute forks or multiple crowns; however, U-shaped forks are permitted above 35 feet. An average of at least one-third of the total height must be in clear length.[3/] In trees 9 inches or less in diameter at breast height, limbs and knots under 1 inch in diameter are permitted in clear length.

Tree class three: Poor growing stock.--Trees that otherwise meet the specifications for tree class two but are competing with class one trees for growing space and trees merchantable for sawlogs or potentially merchantable that do not meet the specifications for the first two classes are included in this class.

Tree class four: Nongrowing stock.--Cull trees and trees with no potential merchantability other than for chemical wood or pulpwood are included in this class.

3/ The average clear length for the tree will be determined by considering the tree to have four faces on its main stem. Each face will include one quarter of the circumference of the tree. The average of the clear length on these four faces will be the average clear length of the tree.

These tree classes should not be used mechanically but, generally speaking, they can be applied as follows:

a. Class four trees should be considered for removal from the stand as quickly as possible consistent with the stocking levels recommended.

b. Class three trees should next be considered for removal. Those that are interfering with good growing stock should be the first ones cut. Most of the intermediate cutting in second-growth stands will come from this tree class. However, there is a substantial range in potential value within the class. Where there is a choice, the marker should leave those trees with the highest future values for later cuts and take his cut from among those individuals whose value will not be increased by additional growth.

c. Class two trees are satisfactory growing stock and should generally be left in the stand until full economic maturity is attained. Immature trees in this class may have to be removed to meet stocking level requirements.

d. Class one trees are good growing stock and should be left until fully mature. The only possible exception to this is in stands where stocking is so high as to require their removal. Even in this rare case the marker should consider the advisibility of accepting slower individual tree growth to obtain higher final values per acre.

The term "vigor" used in this classification describes the health of the tree and its ability to grow at a rapid rate and compete successfully with its neighbors. Little is known about the external indicators of good vigor. However, experience indicates that for any given species and for the same crown size, those trees with the greatest leaf area within the main crown are the most vigorous ones. Leaf color is also an indicator: Yellow or chlorotic-looking leaves denote poor vigor. The bark characteristics of many species are also modified by growth rate and vigor. Tight bark with shallow fissures generally indicates good vigor. In sugar maple, rapidly growing trees show the color of the inner bark at the base of the fissures.

Crown fullness is another term in the classification that lacks specific definition. If the live crown occupies between one-third and one-half of the total height of the tree, crown diameter in relation to the d.b.h. can be considered an expression of crown fullness. For most species in the northern hardwood type, a tree which averages from 1 3/4 to 2 feet of crown diameter for each inch of d.b.h. will grow at close to its maximum rate. This ratio can be used as a guide in determining crown fullness.

A Bibliography of References for Timber Markers in Northern Hardwoods

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2. Gevorkiantz, S. R., and Olsen, L. P.
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   A collection of valuable board-foot, cord, and cubic foot volume tables with instructions for their use and application to Lake States timber.

3. Stoeckeler, J. H., and Arbogast, Carl F.
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